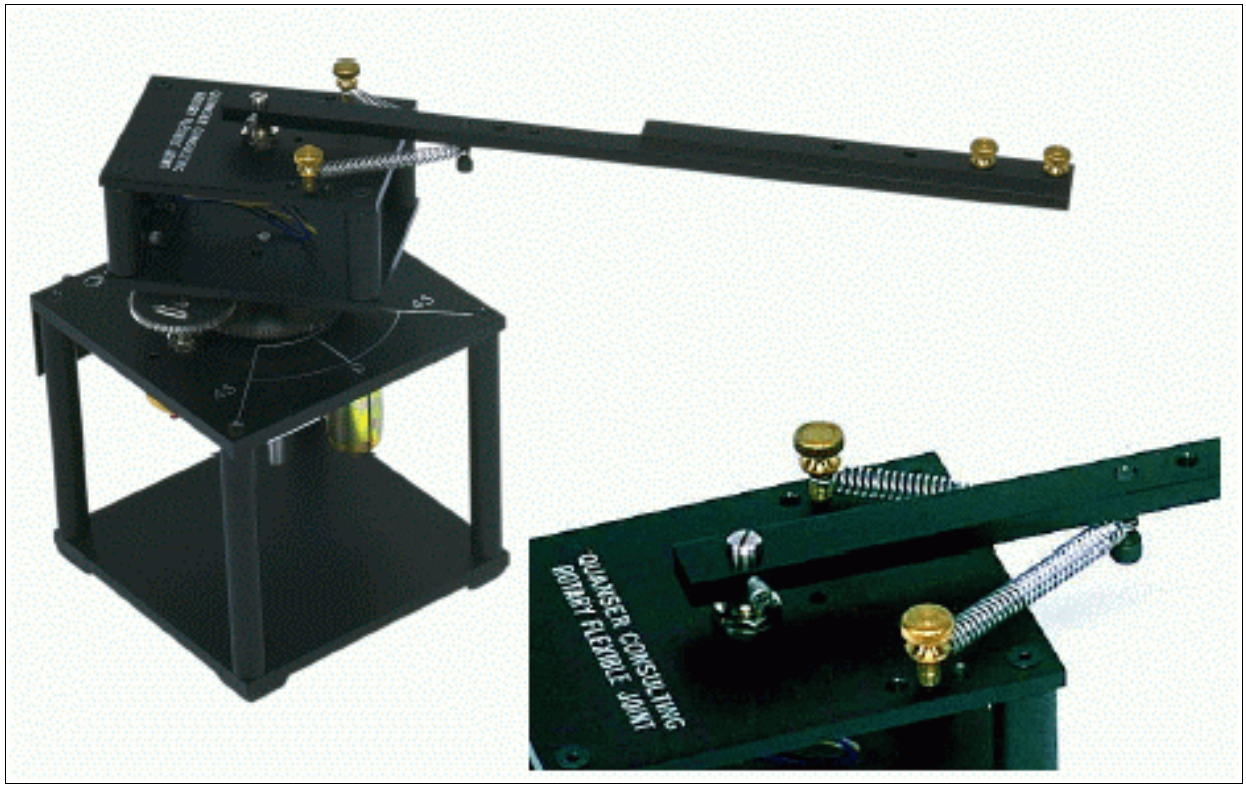
QUANSER
INNOVATE. EDUCATE.

# SRV02-Series

# Rotary Flexible Joint




# User Manual

# Table of Contents

1. Description....3
2. Purchase Options....3
2.1 Modular Options....4
3. System Nomenclature and Components....5
4. System Configuration and Assembly....6
4.1 Changing the springs....8
4.2 Potentiometer (Component 9)....9
4.2 Encoder (Component 4)....9
4.3 Typical Connections for the SRV02 – ROTFLEX Experiment....10
4.4 Testing the ROTFLEX or ROTFLEX-E Sensor....11
5. Rotary Flexible Joint Module – Range of Experiments & Features....12
6. System Requirements & Specifications....13
6.1 System Specifications....13

# Index of Tables

Table 1 - ROTFLEX Options....3
Table 2 - Rotary Family Modules....4
Table 3 - Component Names....5
Table 4 - Typical Connections....10
Table 5 - System Requirements....13
Table 6 - ROTFLEX Specifications....13

# Index of Figures

Figure 1- ROTFLEX top view....5
Figure 2 - ROTFLEX side view....5
Figure 3 - Contents of ROTFLEX package....6
Figure 4 - Attaching to the SRV02....6
Figure 5 - ROTLFEX Model....7
Figure 6 - Step 1: Attached both springs to arm anchor point....8
Figure 7 - Step 2: Selecting a base anchor point....8
Figure 8 - Step 3: Pull the arm towards the final anchor point....9

# ROTFLEX - Rotary Flexible Joint

User Manual

## 1. Description

The rotary flexible joint consists of a rotary sensor mounted in a solid aluminum frame and is designed to mount to a Quanser rotary servo plant. The sensor shaft is aligned with the motor shaft. One end of a rigid link is mounted to the sensor shaft. The link rotation is counteracted by two extension springs anchored to the solid frame resulting in an instrumented flexible joint. The spring anchor points are adjustable to three locations to obtain various stiffness constants. Three types of springs are supplied with the system resulting in a total of 9 possible stiffness values. The link is also adjustable in length thus allowing for variations in inertia.

This system is similar in nature to the control problems encountered in large geared robot joints where flexibility is exhibited in the gearbox. A rigid beam is mounted on a flexible joint that rotates via a DC motor. The joint deflection is measured using a sensor. The rotary flexible joint is an ideal experiment intended to model a flexible joint on a robot or spacecraft. This experiment is also useful in the study of vibration analysis and resonance.

## 2. Purchase Options

The rotary flexible joint is equipped with a sensor to measure the arm's angular position. The module can be equipped with either an analog potentiometer or an optical encoder.

| *Model / Option* | *Description* |
|---|---|
| ROTFLEX | Basic Unit – Potentiometer to sense arm's angular position. |
| (**E**) Option | Encoder Option – 1024 line optical encoder to sense arm's angular position. |

*Table 1 - ROTFLEX Options*

## 2.1 Modular Options

Quanser values itself for the modularity of its experiments. The SRV02 rotary plant module serves as the base component for the rotary family of experiments. This modular philosophy facilitates the change from one experimental setup to another with relative ease of work and a valuable savings in cost. The following table lists the experiments currently available in the rotary family of products utilizing the SRV02 as the base.

| *Module Name* | *Description* |
|---|---|
| Ball & Beam | The Ball & Beam experiment requires the user to manipulate the position of a rolling ball on a beam. |
| Flexible Link | The Flexible Link experiment requires the user to command a *tip* position of the flexible link attached to the SRV02. |
| Flexible Joint | A rigid beam is mounted on a flexible joint that rotates via the SRV02 and the user is to command the tip position of this beam. |
| Gyro/Stable Platform | The purpose is to maintain the line of sight of an instrument mounted on a rotating platform (SRV02). |
| Inverted Pendulum | The purpose is to balance the inverted pendulum through a rotary motion arm (SRV02). |
| Double Inverted Pendulum | The double inverted problem adds to the complexity of the single pendulum by introducing a 2$^{nd}$ pendulum. |
| 2 DOF robot module | This experiment requires the x-y positioning of the “end effector”. |
| 2 DOF Rotary Gantry | This experiment requires the control of the swing of a x-y gantry crane using a 5 DOF linkage. |
| 2 DOF inverted pendulum | Balance a pendulum that is free to fall in 2 directions. The pendulum is attached to the tip of the 2 DOF robot. |

*Table 2 - Rotary Family Modules*

## 3. System Nomenclature and Components

Figure 1 & Figure 2 below depict the ROTFLEX-E module. The standard ROTFLEX is equipped with a potentiometer instead of an encoder as the sensor. Refer to the following table to associate the *components* with their corresponding photographs.

| | | | |
|---|---|---|---|
| 1 | ROTFLEX Base | **6** | Arm anchor points |
| **2** | Thumbscrews | **7** | Springs |
| **3** | ROTFLEX Arm | **8** | Extra load |
| **4** | Arm sensor (Encoder) | **9** | Sensor Connector |
| **5** | Base anchor points | **10** | |

*Table 3 - Component Names*

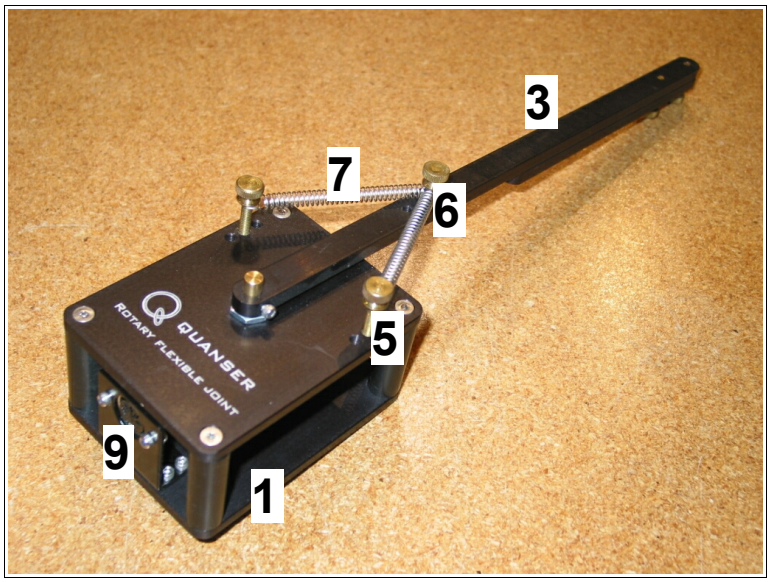



*Figure 1- ROTFLEX top view*

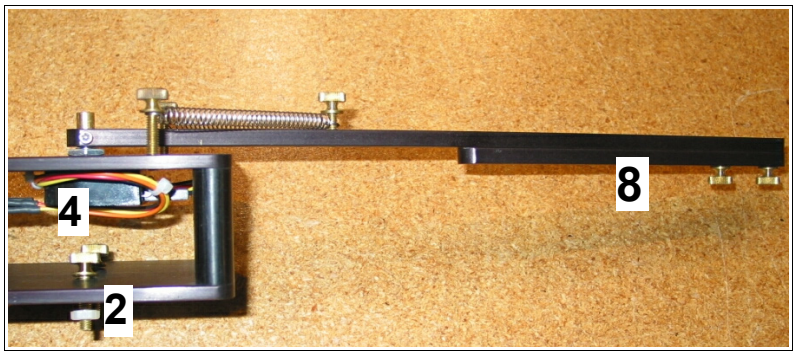



*Figure 2 - ROTFLEX side view*

## 4. System Configuration and Assembly

The rotary flexible joint module requires minimal assembly. Figure 3 Below shows the components of the ROTFLEX package you should have received. **Note the 2 sets of springs. Each set has a different spring constant resulting in 3 sets of springs each with their own stiffness.*

*Figure 3 - Contents of ROTFLEX package*

The only assembly required is to mount the ROTFLEX onto the SRV02. Make sure the SRV02 is configured in the High-Gear configuration. If you are unsure about the SRV02, please refer to the *SRV02 User Guide*. Simply place the ROTFLEX onto the load shaft (middle shaft) and secure the ROTFLEX in place by tightening the 2 thumbscrews as seen in Figure 4 below.

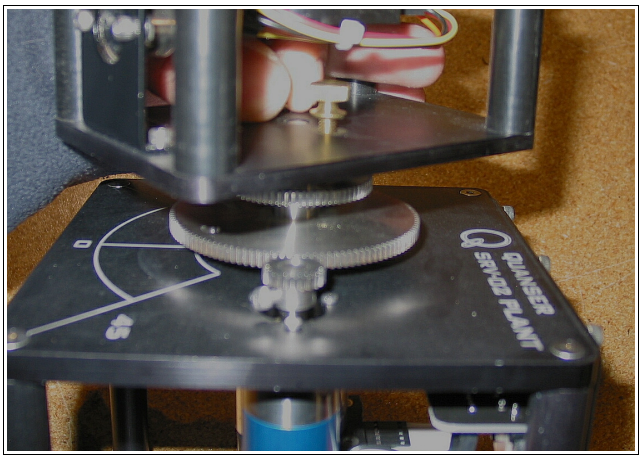



*Figure 4 - Attaching to the SRV02*

Figure 5 Below is a model depicting the rotary flexible joint. The ROTFLEX module has been designed to allow many configurations. As you can see in Figure 5, there are 3 anchor positions on the arm as well as 3 anchor positions on the body. By attaching the springs in different anchor points, it is possible to realize a wide range of spring constants of the joint. There is also an additional load arm provided with the system that allows for variable load inertias. Coupled with the 3 sets of springs (each with a different spring constant), there are **112** distinct system dynamics attainable with this module!

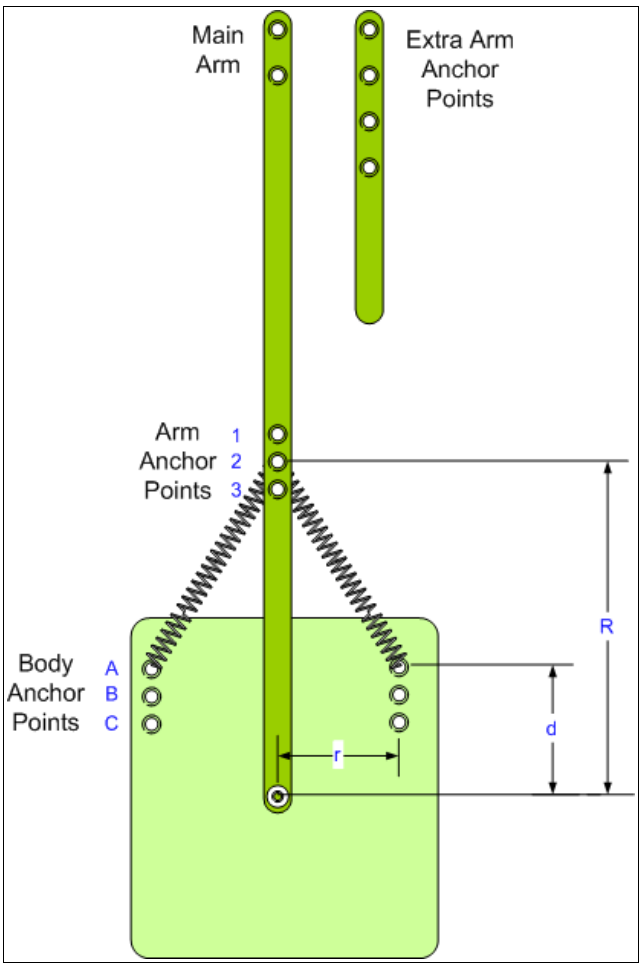



*Figure 5 - ROTLFEX Model*

## 4.1 Changing the springs

The following images will illustrate the proper way to insert a new set of springs or change spring anchor locations. In order to maintain proper system dynamics, the springs and anchor positions should be symmetric (i.e. Do not use 2 springs of different stiffness and make sure both body anchor points are the same). **Using the stiffest set of springs might require some extra effort to insert into the anchor points.*

Take both springs (make sure they are of the same pair) and insert the thumbscrew through the ends of both springs. Screw the thumbscrew into the desired arm anchor point.

*Figure 6 - Step 1: Attached both springs to arm anchor point*

Turn the arm towards you and screw in the thumbscrew into the desired base anchor point as seen in below.

*Figure 7 - Step 2: Selecting a base anchor point*

Finally, pull the arm toward the other base anchor point (you will feel some resistance from the other spring). Screw the remaining thumbscrew into the desired base anchor point. Make sure it is the same point the other spring is in.

*Figure 8 - Step 3: Pull the arm towards the final anchor point*

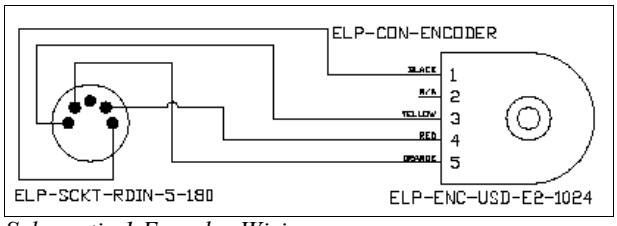
### 4.2 **Potentiometer** (*Component 9*)

The standard rotary flexible joint module (ROTFLEX) uses a potentiometer to sense the arm angle. The model used is a *Vshay Spectrol model 132* potentiometer. It is a single turn, 10k Ohm sensor with a range of approximately ± 45° due to the physical restrictions in the fixture. Its electrical range is 352 degrees. It is biased such that a ± 12 V supply results in a ± 5 V range over the full range of 352 degrees. Under normal operations, terminal three should measure +5 V while terminal 1 should measure -5 V. The actual signal is available at terminal 2. The sensor connection is a 6-pin mini DIN which is designed to be connected to a Quanser UPM (Universal Power Supply). The UPM delivers the bias voltage for the potentiometer (± 12 V) and the sensor signal is then available on the corresponding analog input.

### 4.2 **Encoder** (*Component 4*)

The ROTFLEX-E options come with an optical encoder used to measure the arm's angular position. The model used is a US Digital Optical Kit Encoder. It offers high resolution (4096 counts in quadrature), and measures the *relative* angle of the arm (as opposed to the potentiometer which only measure an *absolute* angle from a pre-defined 0° location).

The Encoder sends a digital signal and should be directly connected to a Quanser terminal board using a standard 5-pin DIN cable. **DO NOT connect the encoder signal to the UPM**. Schematic 1 Is the wiring diagram of the encoder.




*Schematic 1 Encoder Wiring*

### 4.3 Typical Connections for the SRV02 – ROTFLEX Experiment

The following table describes the typical setup using the complete Quanser solution. It is assumed that the ROTFLEX is being used along with an SRV02, UPM and Q8 DAQ board.

| *From...* | *To...* | *Cable* | *Description* |
|---|---|---|---|
| ROTFLEX Potentiometer (*Component 9*)<br>**Only required on the ROTFLEX model.* | *S3* Connector on *UPM.* | 6-pin mini DIN to 6-pin mini DIN. | This cable results in delivering a ±12V bias to the potentiometer and measuring the potentiometer signal voltage on *S3* of the UPM. |
| ROTFLEX-E Encoder (*Component 4*)<br>**Only required on the ROTFLEX-E model.* | *Encoder 1* connector on the terminal board. | 5-pin Stereo DIN to 5-pin Stereo DIN. | The terminal board should supply the encoder with the +5V and ground. The arm signal will then be measure on Encoder channel 1. |
| SRV02 Encoder<br>**This is the load gear position measurement* | *Encoder 0* connector on the terminal board. | 5-pin Stereo DIN to 5-pin Stereo DIN. | The terminal board should supply the encoder with the +5V and ground. The load shaft position signal will then be measure on Encoder channel 0. |
| *'To Load'* Connector on *UPM.* | *Motor* on SRV02. | 6-pin DIN to 4-pin DIN. | This connects the output of the amplifier to the motor. You can use a variety of cables resulting in a different gain from input to output. The cables available are Gain=1, Gain=3, Gain=5. |
| Analog Signals (*To A/D)*<br>** Only required if using analog sensors..* | Analog input channels 0-3 on the DAQ. | 5-pin DIN to 4x RCA. | From the *UPM,* connect all the analog sensor signals to the terminal board such that *S1* is measured on analog input 0. *S2* - AI # 1, *S3* - AI # 2, *S4* - AI # 3. |
| Analog output channel 0 on the DAQ. | *UPM* input (*From D/A)* | RCA to 5-pin DIN. | This is the command output from the DAQ that will be amplified and drive the motor. |

*Table 4 - Typical Connections*

### 4.4 Testing the ROTFLEX or ROTFLEX-E Sensor

This section describes functional tests to determine if your ROTFLEX sensors are operating normally. It does **not** cover any performance tests. All these tests require an understanding of Simulink (or Labview), WinCon (or equivalent), and Q8 (or equivalent data acquisition board you are using). You should be able to *"build"* a controller that can measure and apply desired signals.

In the following sections, it is also assumed that the SRV02 is connected as described in the *Typical Connections* table above.

- **ROTFLEX** with potentiometer sensor - Build a controller that measures analog input # 2 (Make sure the sensor is connected to *S3* on the UPM). Apply a gain block to the signal with a gain of 35.2 (352° over a 10V range). With the controller running, you should be seeing the Arm's angular position. The signal should read 0° when the arm is at its equilibrium (middle) position and should vary by ±40° between the 2 hard stops.

- **ROTFLEX-E** with encoder sensor – Build a controller that measures encoder channel # 1 (Make sure the sensor is connected to encoder channel # 1 on the terminal board). Apply a gain block to the signal of 360/4096 (the encoder generates 4096 counts per revolution). With the controller running, you should be measuring the angle of the Arm. You will realize that the reading is at 0° at the location that the Arm was in when the controller started. The signal should read 0° when the arm is at its equilibrium (middle) position and should vary by ±40° between the 2 hard stops.

Validate that your sensor is behaving according to the normal operation stated above. If the measurements are not as expected, please refer to Table 4 and make sure the connections are made as specified.

For technical support referring to any of the ROTFLEX components, please visit us on the web at: www.Quanser.com.

Under our *Technical Support* section, please fill out a *technical support form* indicating your problem in detail and one of our engineers will be happy to respond to your request.

## 5. Rotary Flexible Joint Module – Range of Experiments & Features

The rotary flexible joint is an ideal experiment intended to model a flexible joint on a robot or spacecraft. This experiment is also useful in the study of vibration analysis and resonance. The student will be exposed to an interesting experiment where they will design a controller to dampen the oscillations of the arm by varying the voltage to the SRV02 motor.

### ROTFLEX Key Features:

- High Quality Aluminum chassis with precision crafted parts
- High Resolution Encoders to sense arm position
- Variable Loads and Spring Anchors
- Variable Spring Stiffness
- Fully documented system models & parameters
- Fast and Easy attachment to the SRV02 plant
- Open Architecture Facilitates Matlab/Simulink Design
- Modular Design
- 112 Distinct Configurations!

### Curriculum Topics:

- System Modeling & Simulation
- Real-Time Control
- Full-State Feedback
- Frequency Analysis
- Vibration & Resonance
- Hardware in the Loop
- Robotics
- Observer Design
- Nonlinear Control

# 6. System Requirements & Specifications

The Rotary Flexible Joint Module (ROTFLEX) is designed as an attachment to the SRV02 plant. Along with the SRV02 plant, the following components are required to complete the experimental setup.

| *Component* | *Quanser Recommended (Common Configuration)* | *Alternative* |
|---|---|---|
| Power Module | Quanser UPM 1503/2405 | Other Power Supply that can deliver the required power. |
| Data Acquisition | Quanser Q8 | dSPACE DS 1104 National Instruments E-Series DAQs<br>Any other DAQ with at least one A/D, one D/A and one Encoder input. |
| Control Software | Quanser WinCon / SLX / WebLab | The Mathworks – RTWT, xPC<br>dSPACE – ControlDesk<br>National Instruments – Labview RT |

*Table 5 - System Requirements*

## 6.1 System Specifications

| *Specification* | *Value* | *Units* |
|---|---|---|
| Module Dimensions | **10 x 8 x 5** | $cm^3$ |
| Main Arm Length | **30** | cm |
| Load Arm Length | **15** | cm |
| Module Body mass | **0.3** | kg |
| Main Arm mass | **0.064** | kg |
| Load Arm mass | **0.03** | kg |
| Potentiometer Bias Power | **±12** | Volts |
| Potentiometer Measurement Range | **±5** | Volts |
| Encoder Resolution | **4096** | Counts/Rev. |
| Spring # 1 Stiffness | **187** | N/m |
| Spring # 2 Stiffness | **313** | N/m |
| Spring # 3 Stiffness | **565** | N/m |

*Table 6 - ROTFLEX Specifications*